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Stock Assessment and Biological Characteristics of Burbot in Lake Louise, Hudson, and Tolsona Lakes, Alaska, 1993

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ABSTRACT

Abundance and indices of abundance were estimated for populations of burbot *Lota lota* in Lake Louise, Hudson, and Tolsona lakes in Southcentral Alaska. Sampling occurred during May and June of 1993. Bootstrapped mean catch per unit of effort of fully recruited burbot (450 mm total length and larger) per 48-hour set ranged from 0.45 (SE = 0.03) in Lake Louise to 3.83 (SE = 0.48) in Tolsona Lake. Abundance during 1992 of fully recruited burbot estimated with mark-recapture experiments was 4,598 (SE = 709) in Lake Louise and 1,579 (SE = 712) in Tolsona Lake. During 1991-1992, annual survival rate for fully recruited burbot in Lake Louise was 72.6%. Abundance of fully recruited burbot in Hudson Lake, estimated by direct expansion using CPUE and spring catchability coefficient, had increased from levels at the closure of the sport fishery.

KEY WORDS: burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, random design, mean length, catch per unit of effort, abundance estimates, survival rates, recruitment.

INTRODUCTION

A major sport fishery for burbot *Lota lota* occurs in the lakes of Southcentral Alaska (Figure 1). Historically, anglers fishing through the ice used baited setlines or jigs to catch and harvest burbot. Harvests of burbot from these lakes increased, on average, 30% annually from 1977 to 1983, with the largest harvest occurring during the years 1984 to 1986 (Mills 1993) (Figure 2). Within the Southcentral region of Alaska, the lakes near Glennallen have supported the largest component of this harvest. During 1984-1986, burbot harvests from these lakes were greater than 10,000 annually, with a peak harvest of over 19,000 burbot during 1985. The Tyone River drainage (consisting of Lake Louise and Susitna and Tyone lakes) supported over half of the burbot harvest in the Glennallen area prior to 1987.

Declining abundance of burbot from overfishing and more restrictive regulations have reduced harvests of burbot in Southcentral Alaska (Vincent-Lang 1993). Emergency regulations adopted in 1987 for many populations reduced the daily bag and possession limits for burbot to a maximum of five fish and reduced the number of simultaneously fished hooks to a maximum of five. In 1988, the Alaska Board of Fisheries further reduced the daily bag and possession limits for road-accessible lakes (Lake Louise, Moose, Susitna, Tolsona, and Tyone lakes) and anglers were restricted to two hooks and limited to two burbot in possession. Continued declines in burbot abundance were documented in Lake Louise and Hudson Lake prompting the closure of their sport fisheries during the fall of 1988. In 1989, the use of setlines was prohibited in the Tyone River drainage. The Alaska Board of Fisheries eliminated setlines as a legal method of sport fishing throughout the Upper Copper/Upper Susitna management area during the 1991 meeting. Interpretation of changes in burbot stock status of the entire Upper Copper/Upper Susitna management area is presented in a report to the Board of Fisheries (Lafferty and Vincent-Lang 1991).

This document is the ninth in a series of annual reports of the findings from this program (Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Potterville and Bernard 1987; Parker et al. 1988, 1989; and Parker 1993). The objectives of the program in the Southcentral region during 1993 were as follows:

1. estimate length composition of fully recruited burbot (≥ 450 mm TL) in Lake Louise, Hudson and Tolsona lakes;

2. estimate abundance of fully recruited burbot (≥ 450 mm TL) in Lake Louise, Hudson and Tolsona lakes; and,

3. estimate annual survival rates for fully recruited burbot (≥ 450 mm TL) in Lake Louise and Tolsona Lake.

Presentation of tables and figures within this series of technical reports remains in similar format to provide easy summarization of time series information (Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Potterville and Bernard 1987; Parker et al. 1988, 1989; and Parker 1993). Each of the populations studied in 1993 has (or had) a popular sport fishery for burbot. Descriptions of each study lake are presented in Appendix A.

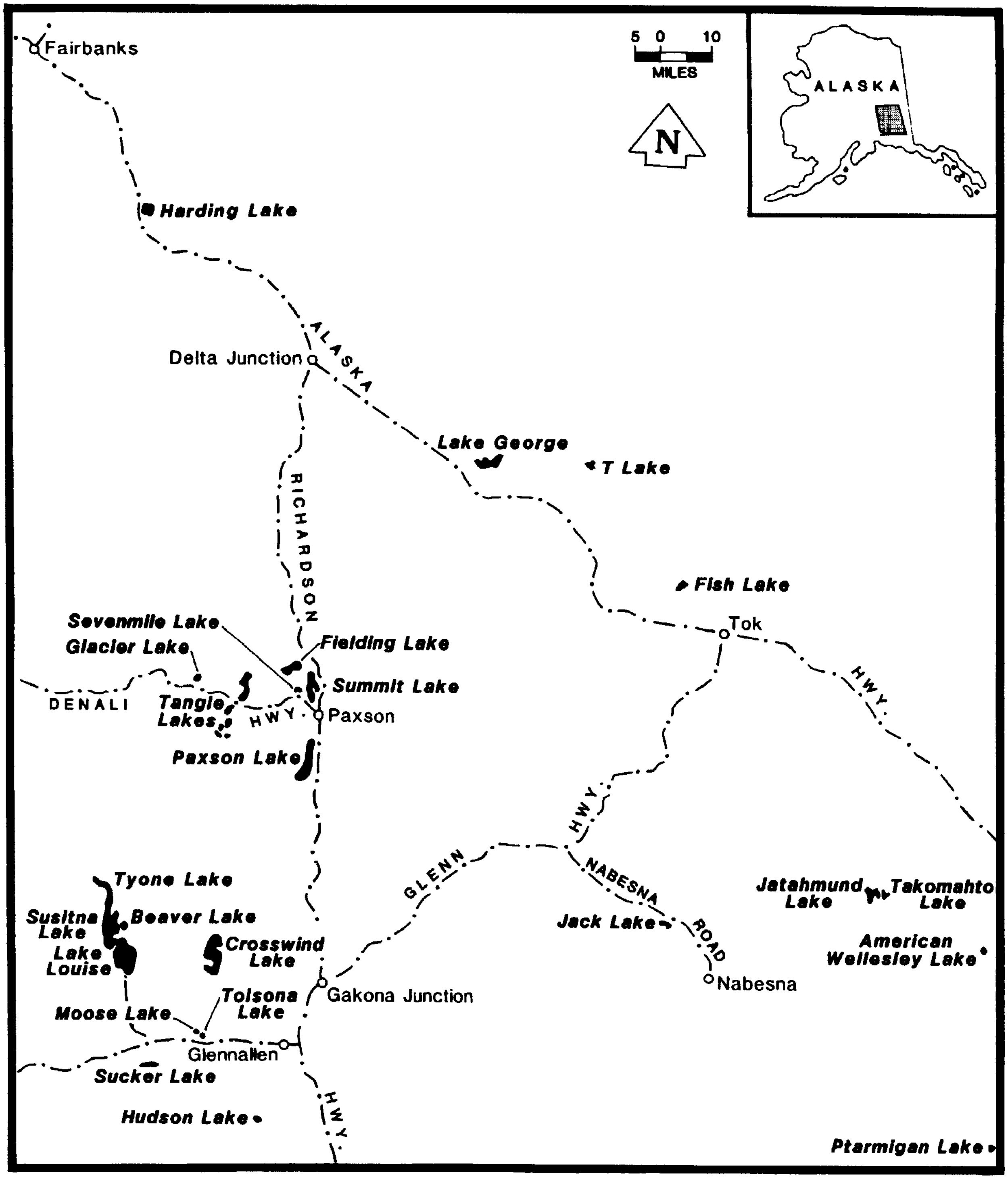

Figure 1. Location of lakes in the Glennallen area with burbot populations that were studied in 1993.

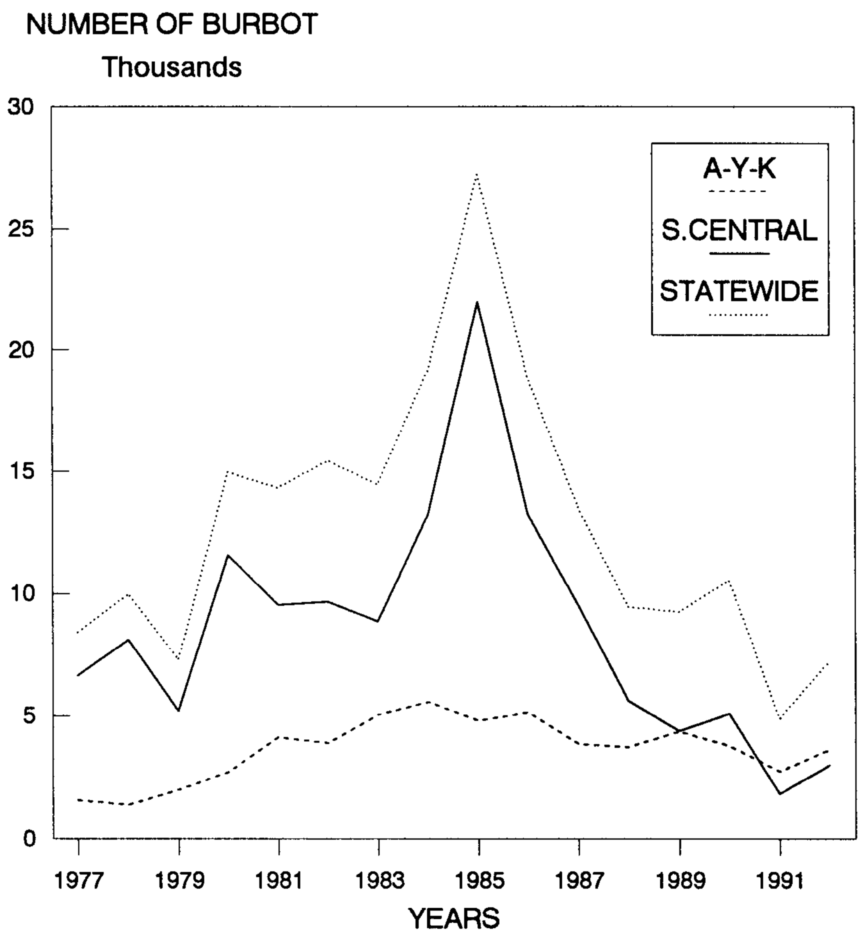

Figure 2. Harvests of burbot in Alaskan sport fisheries, 1977-1992 by region.

METHODS

Gear Description

Burbot were captured in hoop traps 3.05 m in length with seven 6.35 mm steel hoops (Figure 3). Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap was double throated (tied to the first and third hoop) with throats narrowing to an opening 10 cm in diameter. All netting material was knotted nylon with 25 mm bar mesh, held together with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was stretched with two sections of 12 mm galvanized steel conduit which were attached by snap clips to the end hoops of the trap. A numbered buoy was attached to the cod end of the trap with a polypropylene rope. Each trap was baited with Pacific herring *Clupea harengus pallasi* cut into pieces and placed in a 500 ml perforated plastic, screw-top container. Bait containers were placed unattached in the cod end of the hoop trap. Each hoop trap was soaked for approximately 48 hours (hereafter referred to as a set) to maximize the catch of burbot (Bernard et al. 1991).

Study Design

Mean CPUE was estimated in Lake Louise, Hudson, and Tolsona lakes with two-stage, systematic surveys (Table 1). The desired number of sets for each survey in mark-recapture experiments was estimated by dividing an *a priori* estimate of mean CPUE into sample size in numbers of burbot needed for the experiment as per its historical performance. The desired number of sets to estimate mean CPUE as an index of abundance was calculated with procedures in Cochran (1977) for determining sample sizes to estimate the mean of a continuous variable. When both parameters (mean CPUE and abundance) were to be estimated, desired sample sizes for both statistics were calculated and the larger was used. Then, an overlay with parallel transects was placed over a map of each lake at a randomly chosen position but with the transects on the overlay perpendicular to the long axis of the lake. Distances between adjacent transects[1] in the overlay represented 125 m. Each parallel transect had tick marks that represented a distance of 125 m. Next, the desired number of sets was compared with the number of tick marks that were over the water on the map; parallel transects were randomly excluded until the tick marks and the desired number of sets were similar. Traps were set corresponding to the position of each remaining parallel transect. However, the location of the first set along each transect was randomly chosen within 125 m of shore with every subsequent set along that transect at 125 m.

To reduce sampling-induced mortality (often caused by decompression), sets were limited to depths less than 15 meters in Lake Louise. Bernard et al. (1991) showed that burbot recruited fully to hoop traps between 450 mm and

[1] The distance between traps of 125 m was chosen to eliminate gear competition. The effective fishing area of a baited trap was estimated at 0.45 hectare by dividing the average CPUE of burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per hectare from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 hectare to ensure elimination of gear competition; this area corresponds to traps set at a distance of 125 m.

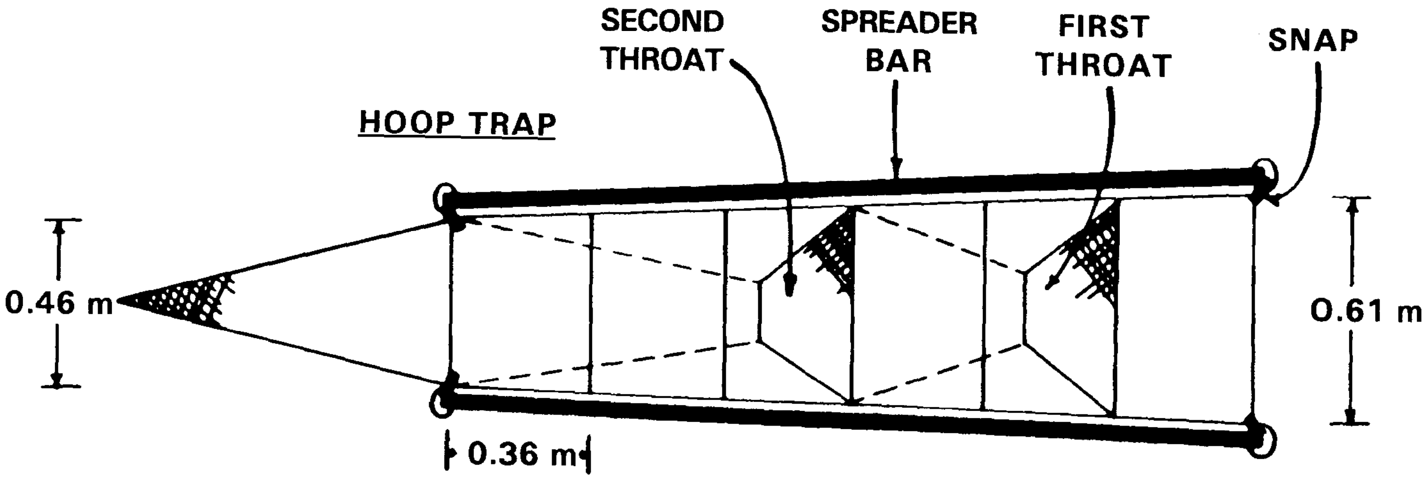

Figure 3. Schematic of hoop traps used to catch burbot in 1993.

Table 1. Number of sets and dates of sampling events for the stock assessment of burbot populations in Lake Louise, Hudson, and Tolsona lakes in 1993.

Lake	Area (ha)	Dates of Sampling Events	Number of Sets
Louise[a]	6,519	6/07-21	1,426
Hudson	259	5/25-31	182
Tolsona	130	5/20-22	60
TOTALS		5/20-6/21	1,668

[a] Sets were restricted to depths < 15 m.

500 mm in total length (TL) in most populations, including the population in Lake Louise. Parker et al. (1989) determined that fully recruited burbot in Lake Louise are equally distributed across depths from early spring throughout the summer. This uniform distribution allows restricting sampling to shallow waters without compromising the accuracy of the mean CPUE as an index of abundance. Mixing of fully recruited burbot across depths occurs within a few weeks of ice-out (Bernard et al. *In press*). Selection of sampling locations in Lake Louise followed the same procedure as in other lakes, only a bathymetric map was used, and all locations greater than 15 m in depth were not considered for sampling. Because partially recruited burbot, < 450 mm TL, are not evenly distributed across depths during summer (Parker et al. 1989), restricting sampling to less than 15 m in depth biased estimates of mean CPUE for that group.

Traps were immersed and retrieved during daylight hours beginning on one end of the lake and progressing to the other end. On Lake Louise, two crews (three members per crew: one person piloted the boat and recorded data while the other two handled traps and measured and tagged captured burbot) immersed and retrieved traps simultaneously. On the smaller lakes, a single crew was used to immerse and retrieve traps. Each crew usually immersed and retrieved from 40 to 60 traps in an 8-hour work day. Every new set received fresh bait, and old bait was discarded on shore.

Captured fish from each trap were placed into a plastic tank containing water. Each burbot was measured and those greater than 300 mm TL were doubly marked. Burbot were tagged with an individually numbered Floy tag inserted in the musculature beneath the anterior portion of the dorsal fin. Throughout the mark-recapture experiments, Floy tags were attached in serial order to allow easy recognition of specific locations and sampling events. The second mark, which was used to evaluate loss of Floy tags, was a left ventral fin clip in 1993. The left ventral (1990) or right ventral fin clip (1991), or a left opercular punch (1992) have been used as secondary marks in a three year rotation. Any burbot that were injured during handling were killed and dissected. Otoliths were removed and the sex and maturity of these burbot were recorded. Ages were estimated from whole, polished otoliths by counting annuli according to the methodologies of Beamish and McFarlane (1987) and Chilton and Beamish (1982). Age composition is reported when sufficient (25) mortalities occurred within a survey.

<u>Abundance, Survival Rates, Recruitment and Mean CPUE</u>

Abundance, survival rates, and recruitment of burbot (≥ 450 mm TL) were estimated with mark-recapture experiments using the multi-event model of Jolly (1965) and Seber (1965). Estimates were calculated with the computer program JOLLY (Model A) as described in Pollock et al. (1985, 1990). Mark-recapture histories for all populations studied in 1993 are in Appendix B1. Recaptures during a single annual survey were considered captured only once to estimate abundance with the mark-recapture experiments. For those populations that have been in the stock assessment program since 1986, a combination of estimation methods (Jolly 1965; Seber 1965, 1982; and Chapman 1951) were used to extend the range of the estimates according to the approach suggested in Pollock (1982).

Mean CPUE was estimated for fully and partially recruited burbot following a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Sukhatme et al. 1984). Although all transects had an equal probability of being included in a survey, they were of different lengths depending upon the shape of the lake. Under these conditions, an unbiased estimate of mean CPUE is:

$$\overline{CPUE} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m_i} \sum_{j=1}^{m_i} \omega_i c_{ij} \tag{1}$$

where:

c_{ij} = catch of burbot from the jth set on the ith transect;

n = number of transects;

m_i = number of sets sampled on the ith transect;

ω_i = $M_i/\overline{M}$;

M_i = maximum possible sets on the ith transect; and

$\overline{M}$ = mean of possible sets across all transects.

Although the M_i and $\overline{M}$ are unknown, the m_i and $\overline{m}$ were used as substitutes because both M and m are directly related to the length of transects. Thus $\hat{\omega}_i = m_i/\overline{m}$ was used to estimate ω_i. Because few burbot enter traps during daylight (Bernard et al. 1991), catches were not adjusted for the few hours deviation in soak times from the standard 48 hours for most sets. Estimates of mean CPUE were also not adjusted for recaptured burbot. A two-stage, resampling procedure (Efron 1982; Rao and Wu 1988) was used to generate an empirical distribution of mean CPUE for each survey from which variance of mean CPUE and bias from using $\hat{\omega}$ were estimated (see Appendix D). In resampling procedures, sets were chosen randomly even though the original selection of sets was systematic. Systematically drawn data can be treated as randomly drawn with little concern for bias in the resultant statistics only so long as these data are not autocorrelated nor follow a trend (Wolter 1984). Analysis of data from surveys has revealed no meaningful trends or autocorrelations among catches along transects (Bernard et al. *In press*)

Mean CPUE was used to estimate abundance of fully recruited burbot in Hudson Lake in 1993 using the relationship:

$$\hat{N} = A\,(\overline{CPUE})\,\hat{q}^{-1} \tag{2}$$

where A is the surface area of Hudson Lake (259 hectares) and q is the catchability coefficient (the fraction of the population removed instantaneously with one unit of sampling effort). Estimates of q were obtained from previous sampling in Hudson Lake in 1987 and 1988 and from sampling other populations since 1986. In 1987 and 1988, sampling at Hudson Lake occurred during mid-June, mid-July, and late September when catchability of burbot is lower. Sampling at Hudson Lake in 1993 occurred in late May when catchability is higher. This discrepancy in timing was resolved by adjusting for the seasonal difference in surveys. Lafferty and Bernard (1993) and Bernard et al. (*In press*) showed that catchability of burbot with baited hoop traps set shortly after lakes become ice-free is about 1.5 times higher than later in the summer and early fall. The estimated catchability coefficient for fully recruited burbot caught in 1987 in Hudson Lake is 0.20 (Lafferty and Bernard 1993); 0.30 [=1.5(0.20)] is then an estimate of q for spring sampling at Hudson Lake.

RESULTS

Burbot in lakes closed to fishing (Lake Louise and Hudson Lake) were larger than burbot exposed to fishing in Tolsona Lake (Figure 4, Table 2). Two percent of burbot caught in Lake Louise and 10% of burbot captured in Hudson Lake were >750 mm TL; no burbot >750 mm TL were captured at Tolsona Lake. Length frequency of burbot captured at Hudson Lake was bimodal with modes at 575 mm and 725 mm TL.

Although estimates of abundance and survival rate for Lake Louise were similar to past years, recruitment was at an all time low (Table 3). Most recent estimates of all three parameters increased for the population in Tolsona Lake (Table 3). Because sampling at Tolsona Lake bisected the calendar year, annual rates of survival for this population are products of rates in Table 3 adjusted for time between sampling events in months. The estimated annual survival rate in Tolsona Lake from 1990-1991 is 0.257 $[=\{(0.375)(0.686)\}^{12/12}]$ and 0.378 $[=\{(0.378)(1.0)\}^{12/13}]$ from 1991-1992. Density of fully recruited burbot in 1992 was 0.71 fish per hectare in Lake Louise and 12.15 in Tolsona Lake (Table 4). Of the fully recruited burbot released in 1992 and recaptured in 1993, 2.5% had lost their tags at Lake Louise and 14.3% at Tolsona Lake.

Mean CPUE of fully recruited burbot in 1993 (Table 5) was similar to earlier statistics for populations in Tolsona Lake and Lake Louise and higher for the population in Hudson Lake. Mean CPUE was 3.14 (SE = 0.51) during sampling at Tolsona Lake from 11-13 June 1992 (Lafferty and Bernard 1993). Although mean CPUE was higher at Tolsona Lake in 1993 (3.83, SE = 0.48), the difference is not functional. Mean CPUE was 0.41 during sampling at Lake Louise in 1992 (Lafferty and Bernard 1993) and was 0.45 a year later (Table 5), again, a non-functional difference. Statistics for the population in Hudson Lake for previous years are not directly comparable to mean CPUE in 1993 because sampling in 1993 occurred in May. However, adjusting measured mean CPUE for the differences in seasons produces a "summer" statistic of 1.76 [=2.64/1.5]. Mean CPUE was 1.14 and 1.20 in the two surveys in 1988 (Parker et al. 1989). From Equation 2, estimated abundance of burbot $\geq$ 450 mm TL in Hudson Lake in 1993 is 2,279 (Table 6). Statistics concerning the mean CPUE for partially recruited burbot are listed in Table 7.

Several additional appendices (B1, B2, B3, and C) provide continuity among previous annual reports or summarize information that could be useful to the reader. Appendix B1 contains mark-recapture histories of Lake Louise and Tolsona Lake. Estimated mean length-at-age for burbot sampled from Hudson Lake is shown in Appendix B2. Appendix B3 is a listing of the data for each

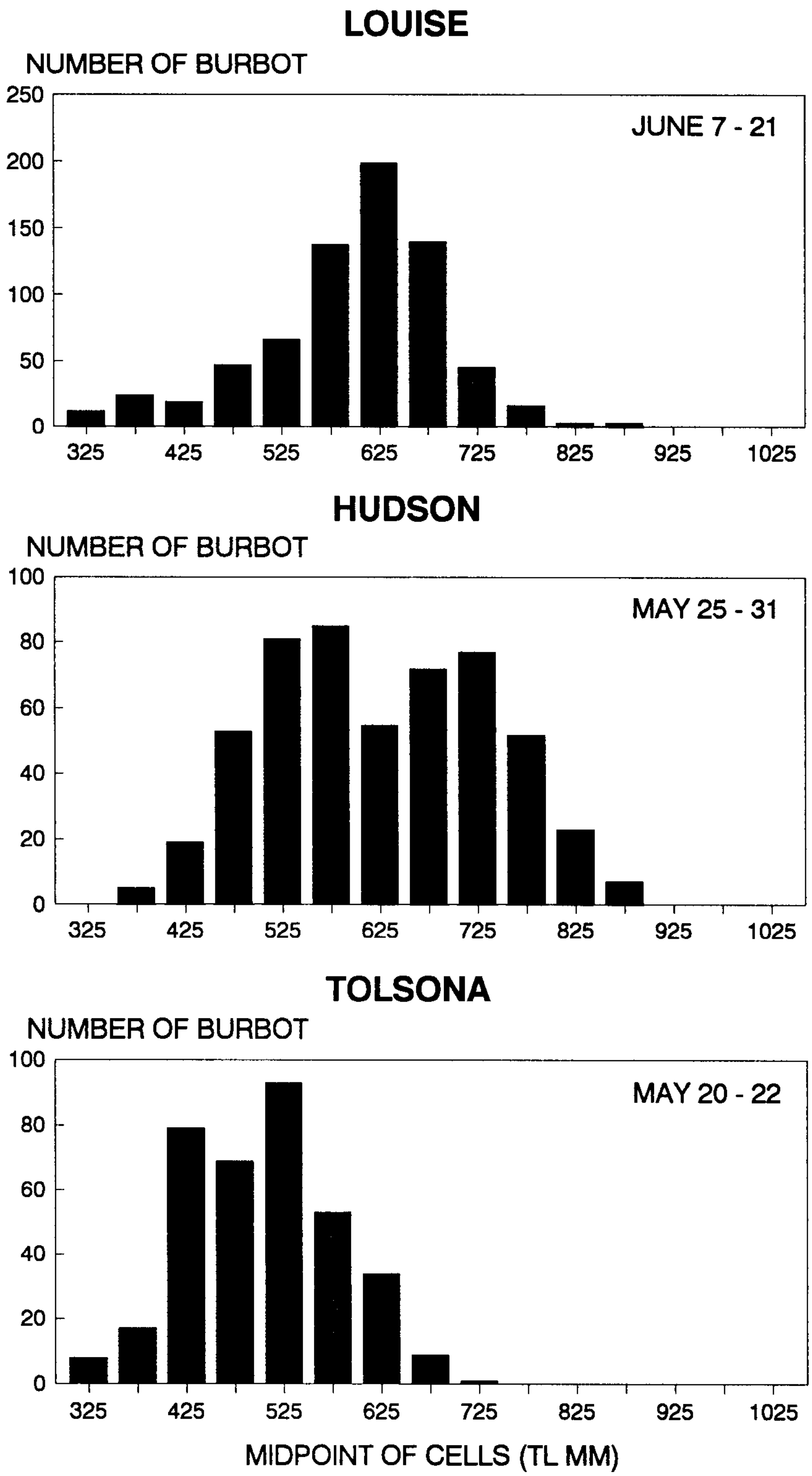

Figure 4. Length-frequency histograms of burbot captured in Lake Louise, Hudson, and Tolsona lakes in 1993.

Table 2. Mean lengths (mm TL) of burbot measured during sampling events in Lake Louise, Hudson, and Tolsona lakes in 1993.

Lake	Statistic	Partially[a] Recruited	Fully Recruited	All
Louise	Mean	372	598	575
	SE	7	3	4
	Samples	72	642	714
Hudson	Mean	416	620	602
	SE	4	5	5
	Samples	45	484	529
Tolsona	Mean	396	526	477
	SE	4	3	4
	Samples	138	230	368

[a] Burbot partially recruited to the gear are < 450 mm TL and fully recruited burbot are ≥ 450 mm TL.

Table 3. Estimates of abundance, survival rates, and recruitment for fully recruited (≥ 450 mm TL) burbot residing in Lake Louise and Tolsona Lake.

		Days between	Abundance			Survival Rate %		Recruitment	
Lake	Date	events	Est.	(SE)	CV %	Est.	(SE)	Est.	(SE)
Louise	6/25/86		6,990[a]	(2,131)	30.5				
		381				29.6	(5.7)	1,864	(2,032)
	7/06/87		3,625	(990)	27.3				
		330				94.8	(15.7)	2,935	(1,434)
	6/11/88		6,101	(1,408)	23.1				
		357				50.5	(6.8)	1,117	(799)
	6/01/89		4,152	(666)	16.0				
		360				58.3	(6.0)	1,151	(473)
	6/04/90		3,571	(424)	11.9				
		360				89.0	(10.3)	1,953	(530)
	6/03/91		5,126	(672)	13.1				
		372				72.6	(11.3)	878	(457)
	6/16/92		4,598	(709)	15.4				
Tolsona	9/26/86[a]		1,901[a]	(120)	21.6				
		237				60.0	(4.6)	138	(209)
	6/25/87		1,291	(120)	9.3				
		336				74.3	(6.6)	616	(136)
	5/26/88		1,571	(165)	10.5				
		96				77.1	(8.8)	68	(124)
	9/01/88		1,280	(155)	12.1				
		267				74.2	(9.3)	612	(135)
	5/24/89		1,562	(178)	11.3				
		112				95.8	(15.6)	152	(156)
	9/13/89		1,648	(271)	16.4				
		241				48.1	(9.6)	558	(161)
	5/24/90		1,351	(241)	17.8				
		124				37.5	(6.6)	90	(75)
	9/07/90		597	(91)	15.2				
		256				68.6	(12.3)	820	(175)
	5/22/91		1,230	(222)	18.0				
		112				37.8	(7.2)	85	(84)
	9/12/91		550	(108)	19.6				
		276				100.0[b]	(64.9)	791	(397)
	6/11/92		1,579	(712)	45.1				

[a] Estimate obtained from Potterville and Bernard (1987).

[b] Actually computed at 143.7. Since this value is impossible, estimate was truncated to 100.

Table 4. Estimated density of fully recruited ($\geq$ 450 mm TL) burbot in Lake Louise and Tolsona Lake during 1992.

Lake	Date	Estimated Abundance	SE	Area of Lake (ha)	Estimated Density (burbot/ha)	SE
Louise	6/16-30	4,598	708	6,519	0.71	0.11
Tolsona	6/11-13	1,579	712	130	12.15	5.48

Table 5. Estimated mean CPUE of fully recruited (≥ 450 mm TL) burbot from systematic sampling of populations studied in 1993.

Lakes and Dates	Strata	Number of Sets and Transects[a]		Mean CPUE			Bootstrapped	
				Bootstrapped	Arithmetic	%Δ	SE	CV
Louise 6/7-21	<15 meters	1,425	71	0.45	0.45	0.1%	0.03	7.6%
Hudson 5/25-31	All depths	181	20	2.64	2.64	-0.1%	0.20	7.5%
Tolsona 5/20-22	All depths	60	8	3.83	3.83	0.1%	0.48	12.5%

[a] Single set transects were deleted from the calculation of mean CPUE.

Table 6. Estimated abundance of fully recruited (≥ 450 mm TL) burbot in Hudson Lake[a] from 1987-1993.

Year	Date	CPUE	SE	Catchability Coefficient	Estimated Abundance
1987	6/15	3.69	0.41	0.25[b]	3,823
	7/06	2.96	0.29	0.20[b]	3,833
1988	7/13	1.14	0.17	0.20	1,476
	9/29	1.20	0.13	0.20	1,554
1989	7/11	0.94	0.13	0.20	1,217
1990	7/11	0.73	0.04	0.20	945
1991[c]					
1992[c]					
1993	5/25	2.64	0.20	0.30	2,279

[a] Surface area of Hudson Lake is 259 hectares.

[b] Estimated with mark-recapture experiments and mean CPUE.

[c] Abundance was not estimated in 1991 and 1992.

Table 7. Estimated mean CPUE of partially recruited (< 450 mm TL) burbot from systematic sampling of populations studied in 1993.

Lakes and Dates	Strata	Number of Sets and Transects[a]		Mean CPUE			Bootstrapped	
				Bootstrapped	Arithmetic	%Δ	SE	CV
Louise 6/7-21	<15 meters	1,425	71	0.05	0.05	0.2%	0.01	20.7%
Hudson 5/25-31	All depths	181	20	0.24	0.24	-0.2%	0.06	23.7%
Tolsona 5/20-22	All depths	60	8	2.27	2.28	-0.7%	0.38	16.8%

[a] Single set transects were deleted from the calculation of mean CPUE.

specific study lake and the custodian. A graphic presentation of the catch by depth for partially and fully recruited burbot in 1993 is presented in Appendix C.

DISCUSSION

Potential bias in the estimates of abundance, survival rate, and recruitment from the mark-recapture experiments was negligible. Only eight of the 190 recaptured burbot in Lake Louise and Tolsona Lake in 1993 had lost their tags; however, secondary marks allowed these recaptures to be identified to the appropriate marking event. The small number (19) of recaptured burbot in Tolsona Lake accounts for the higher than average tag loss percentage during 1993. This tag shedding is not solely from poor tag placement: several anglers had removed tags from burbot, returned the fish into the lake and forwarded tags to department personnel. Since 1986, only one burbot that was tagged in Susitna or Tyone lakes has been recaptured in Lake Louise and eight burbot tagged in Lake Louise have been recaptured in Susitna or Tyone lakes (Lafferty and Bernard 1993). However, these movements are considered rare and have little effect on mark-recapture experiments. Other sources of potential bias in estimates (trap-induced behavior, unequal probabilities of capture and survival) were avoided by following sampling protocols and procedures outlined in Bernard et al. (1991). The nonsensical estimate of survival rate in Tolsona Lake between September 1991 and June 1992 is due to the small number of recaptures in 1993. Since accuracy and precision of estimates in these kinds of mark-recapture experiments improves as recaptured fish are tallied across the years, survival rate for this period should drop as data accumulate.

Abundance of fully recruited burbot in Lake Louise and Tolsona Lake in 1992 is about the same as in 1991. Burbot abundance in Lake Louise is still depressed in relation to the harvest estimate of 3,710 during 1985. The length frequency histogram of burbot in Lake Louise indicates little improvement in the stock status through growth recruitment. The length frequency histogram of burbot in Tolsona Lake indicates an increase in the number of burbot recruiting into the population through growth. Unlike Lake Louise where there was no growth recruitment, burbot abundance in Tolsona Lake is relatively stable in relation to previous abundance estimates at similar seasons.

The burbot population of Hudson Lake has rebounded somewhat from lower abundance levels in 1988-1990. An adjusted mean CPUE of 1.76 for summer 1993 is considerably higher than mean CPUE in the summer since the lake was closed to sportfishing (0.73 to 1.14 from 1988 to 1990). Mean CPUE for summer 1987, a year prior to the high exploitation of the fishery, was 2.96. There is a significant difference in length frequency histograms from 1987 and 1993, due to the bimodal distribution in 1993. The first mode is at 575 mm, indicating growth recruitment into the fishery. The second mode at 725 mm had four times as many fish at this category than in 1987, and reflects the closure of the sport fishery, as the size class recruited into the fishery in 1988 was allowed to grow unexploited.

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APPENDIX A

Appendix A. Description of lakes with burbot populations sampled in 1993.

LAKE LOUISE (62°20′ N, 146°30′ W) is the largest lake in a three-lake system that is accessible by the Glenn Highway on a 25 km gravel road. Lake Louise is 6,519 hectare with maximum depth of 51 m and an elevation of 720 m. A state campground with boat launch is available. Four lodges are found along the south end of the lake, and numerous cabins are located around the shore. Lake Louise has supported year-round fishing for Arctic grayling *Thymallus arcticus*, lake trout *Salvelinus namaycush*, and round whitefish *Prosopium cylindraceum*.

HUDSON LAKE (61°53′ N, 145°40′ W) is a remote lake 19 km southwest of Copper Center. Hudson Lake is 259 hectare with a maximum depth of 16 m and an elevation of 655 m. Although there are no cabins or public recreational facilities at the lake, there was a large winter ice fishery for burbot. Hudson Lake contains Arctic grayling, burbot, longnose suckers, rainbow trout, and round whitefish.

TOLSONA LAKE (62°06′ N, 146°04′ W) is accessible from the Glenn Highway. Tolsona Lake is 130 hectare with a maximum depth of 4 m and an elevation of 625 m. Tolsona Lake has numerous cabins and one lodge. No public recreational facilities are available. This lake has had a popular burbot fishery in the winter in recent years. Tolsona Lake has Arctic grayling, longnose suckers, stocked rainbow trout, and other species.

APPENDIX B

Appendix B1. Mark-recapture histories of fully recruited[a] burbot by year for the populations in Lake Louise and Tolsona Lake.

LAKE LOUISE								
DATE: Year	1986	1987	1988	1989	1990	1991	1992	1993
Beginning	6/25	7/06	6/11	6/01	6/04	6/03	6/16	6/07
Ending	9/02	8/19	6/24	6/16	6/19	6/14	6/30	6/21
NUMBER OF FULLY RECRUITED BURBOT:								
Recaptured from Event 1	0	19	9	12	2	2	1	2
Recaptured from Event 2		0	19	12	15	3	3	2
Recaptured from Event 3			0	32	21	12	6	3
Recaptured from Event 4				0	72	34	22	12
Recaptured from Event 5					0	73	43	48
Recaptured from Event 6						0	59	37
Recaptured from Event 7							0	58
Recaptured from Event 8								0
Captured with Tags	0	19	28	56	110	124	134	162
Captured without Tags	523	501	494	573	607	497	423	450
Captured	523	520	522	629	717	621	557	612
Released with Tags	470	235	430	625	714	618	554	609

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TOLSONA LAKE												
DATE: Year	1986	1987	1988	1988	1989	1989	1990	1990	1991	1991	1992	1993
Beginning	9/23	6/02	5/25	8/30	5/23	9/12	5/22	9/05	5/20	9/09	6/11	5/20
Ending	10/10	6/04	5/27	9/01	5/25	9/14	5/24	9/07	5/23	9/12	6/13	5/22
NUMBER OF FULLY RECRUITED BURBOT:												
Recaptured from Event 1	0	123	35	14	5	3	5	9	0	0	0	0
Recaptured from Event 2		0	79	32	33	18	11	5	1	1	0	0
Recaptured from Event 3			0	51	36	13	11	8	0	0	0	0
Recaptured from Event 4				0	45	13	4	5	3	0	0	0
Recaptured from Event 5					0	63	14	8	10	2	0	0
Recaptured from Event 6						0	22	9	5	2	0	0
Recaptured from Event 7							0	21	15	2	2	0
Recaptured from Event 8								0	33	7	8	2
Recaptured from Event 9									0	35	14	8
Recaptured from Event 10										0	27	3
Recaptured from Event 11											0	6
Recaptured from Event 12												0
Captured with Tags	0	123	114	97	119	110	67	65	67	49	51	19
Captured without Tags	531	379	236	118	239	139	148	115	296	88	145	210
Captured	531	502	350	215	358	249	215	180	363	137	196	229
Released with Tags	531	497	350	215	358	249	215	180	362	136	196	225

[a] Fully recruited burbot are ≥450 mm TL.

Appendix B2. Estimated mean length-at-age for burbot sampled from Hudson Lake in 1993.

Hudson Lake		Age														
Sex	Statistic	3	4	5	6	7	8	9	10	11	12	13	14	15	16	n
Male	Sample Size	0	0	0	0	1	1	1	2	0	2	0	2	0	0	9
	Mean Length					425	520	645	655		688		758			
	SE								67		16		9			
Female	Sample Size	0	0	1	1	0	2	3	4	3	4	0	0	0	0	18
	Mean Length			420	460		563	685	699	785	721					
	SE						30	19	15	28	25					
Combined	Sample Size	0	0	1	1	1	3	4	6	3	6	0	2	0	0	27
	Mean Length			420	460	425	548	675	684	785	721		758			
	SE						23	17	26	28	19		9			

Appendix B3. Summary of data archives.

Location	Project Leader	Storage Software and version
Anchorage	R. Lafferty 745-5016	Comma delimited ASCII files Standard RTS Archive format[a]

Lake	Data Map File Name	Data Format	Software
Louise	I0100H-3.dta	Hoopnet	RTS-ASCII
	LOU93TD.dbf	Tag History	Dbase
Hudson	I0090H-3.dta	Hoopnet	RTS-ASCII
	HUD93TD.dbf	Tag History	Dbase
Tolsona	I2860h-3.dta	Hoopnet	RTS-ASCII
	TOL93TD.dbf	Tag History	Dbase

Definitions of Data Formats:

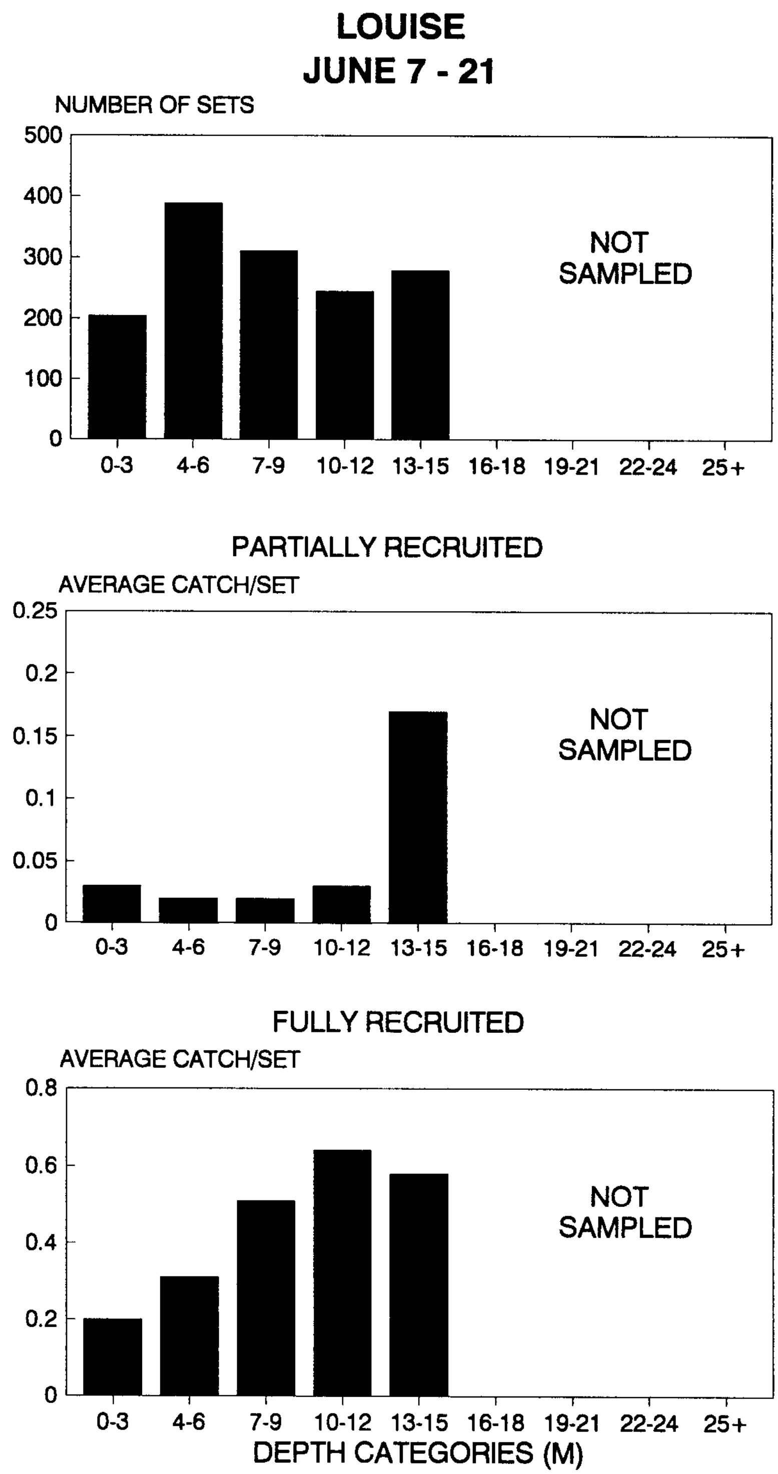
Hoopnet: a mark-sense form developed by Alaska Department of Fish and Game, Division of Sport Fish-Research and Technical Services (RTS) for the recording of trap, catch, and tagging information.

Tag History: a Dbase file that contains lake specific historical tagging information by individual tags and recaptures by sampling events.

Specific codes and organization of columns for each data format are available on request from RTS.

[a] Alaska Department of Fish and Game-Division of Sport Fish-Research and Technical Services (RTS).

APPENDIX C



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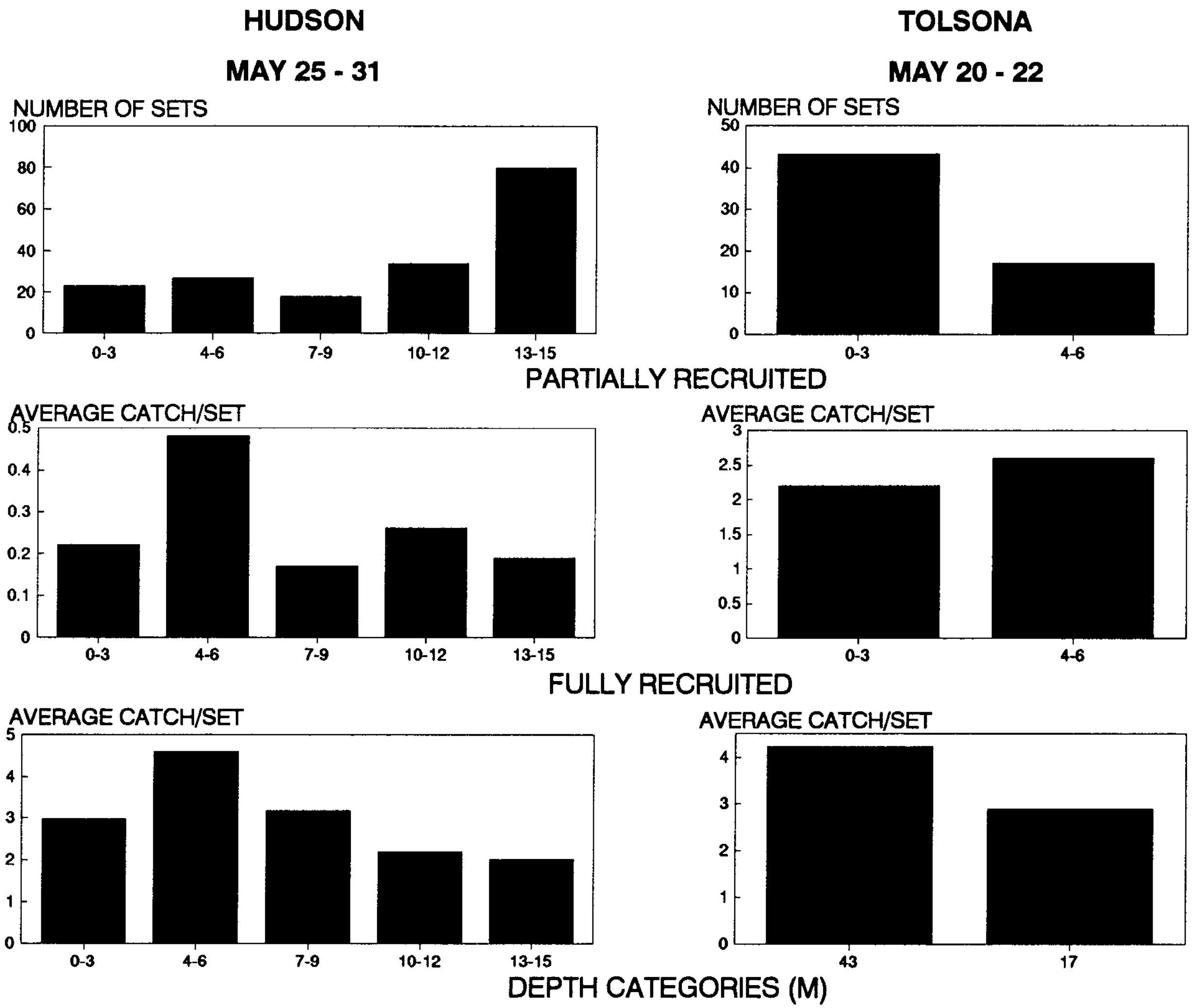
Appendix C. Frequency of sets by depth and average catch of burbot by depth in Lake Louise, Hudson, and Tolsona lakes in 1993.



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APPENDIX D

Appendix D. Bias and variance of mean CPUE.

Variance of mean CPUE, its empirical distribution, and its bias were estimated for each survey with the resampling techniques of Efron (1982). Each survey produced data $\{c_{ij}\}$ in which c_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m_i$. One thousand bootstrap samples (B=1000) were drawn by resampling these original data with replacement. For each bootstrap sample, n transects were randomly chosen with replacement from the n transects in each survey, then from each chosen transect, m_i catches were randomly drawn from the m_i sets on that transect. Although sets were selected systematically on each transect to produce the original data, catches were presumed to be independently distributed along each transect, a situation for which random selection of catches would be unbiased (Wolter 1984). Each bootstrap sample can be expressed as $\{c^*_{ij}\}_b$ in which c^*_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m^*_i$ and $b=1,B$. Since transects were chosen during the resampling with equal probability even though they were of different sizes, the $\{c^*_{ij}\}$ were scaled appropriately with the technique suggested by Rao and Wu (1988):

$$\tilde{c}_{ij} = \overline{CPUE} + \left\{\frac{n}{n-1}\right\}^{1/2} (\hat{\omega}^*_i \bar{c}^*_i - \overline{CPUE}) + \hat{\omega}^*_i \left\{\frac{m^*_i}{m^*_i - 1}\right\}^{1/2} (c^*_{ij} - \bar{c}^*_i) \qquad (D.1)$$

where $\hat{\omega}^*_i = m^*_i/\bar{m}^*$, $\overline{CPUE}$ = mean CPUE from the original data (from Equation 1), and $\{\tilde{c}_{ij}\}$ = appropriately weighted, resampled catch statistics. The estimate of mean CPUE from the bootstrap estimate is calculated as:

$$\overline{CPUE}^* = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m^*_i} \sum_{i=1}^{m^*_i} \tilde{c}_{ij} \qquad (D.2)$$

The B bootstrap estimates of mean CPUE comprise the empirical distribution F (mean $CPUE^*_1$,....mean $CPUE^*_B$) for the original estimate mean CPUE from Equation 1 as obtained through resampling. Variance of mean CPUE from the original data can be estimated as the population variances of the bootstrap samples:

$$V[\overline{CPUE}] = \frac{\sum_{b=1}^{B} (\overline{CPUE}^*_b - \overline{\overline{CPUE}}^*)^2}{B - 1} \qquad (D.3)$$

-continued-

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where:

$$\overline{\overline{CPUE}}^{*} = \frac{\sum_{b=1}^{B} \overline{\overline{CPUE}}^{*}_{b}}{B} \tag{D.4}$$

The difference between $\overline{\overline{CPUE}}^{*}$ and the original statistic $\overline{CPUE}$ is an estimate of bias in the original statistic.

The $\{c_{ij}\}$ were resampled with a computer program based on Microsoft™ FORTRAN that included subroutines from IMSL, Inc. of Houston, TX for the generation of uniformly distributed random numbers.